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NASA CASE NO. LAR-13,519-1

PRINT FIG. 1

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(NASA-Case-LAR-13519-1) MINING VOLUME  
MEASUREMENT SYSTEM Patent Application  
(NASA) 11 p

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AWARDS ABSTRACT

MINING VOLUME MEASUREMENT SYSTEM

NASA CASE NO. LAR 13519-1

The invention relates to a method and apparatus for a mining volume measurement system.

The invention compares a shaft having a straight or curved primary segment with smaller off-shooting segments to a warn guide. An acoustic generator 34 generates an incident signal 28 into the primary segment 12. The incident signal 28 is a low frequency sound signal that propagates and is guided by the primary segment 12. As a result, the incident signal 28 is not travelling into the off-shooting segments 14 or scattering off the shaft wall 20. A microphone 36 is located adjacent the acoustic generator 34 to receive acoustic signals from the primary segment 12. Upon the generation of the incident signal 28 into the primary segment 12, a reflected signal 30 is generated towards the entry 16 upon the incident signal 28 impinging a boundary, either opened or closed, at an end portion 18 of the primary segment 12. Adjusting the frequency of the incident signal 28 and thereby the reflective signal 30 provides a standing signal 32. The standing signal 32 represents either a fundamental frequency mode or harmonic mode which is characteristic of the primary segment 12. The standing signal 32 can then be utilized to calculate the length of the shaft and thereby the volume of the shaft. Alternatively, a first standing signal 32 is produced which is characteristic of a harmonic or resonance mode. A second standing signal 32 is then produced which is indicative of another harmonic mode which is different from the first standing signal by an integral of  $\pm 1$ . Again, the length of the shaft 10 can then be calculated and thus the volume of it.

The novel features of this invention appear to lie in the accuracy of measurement, notwithstanding the existence of off-shooting segments from the primary segment. Furthermore, the invention eliminates the need for a comparison measurement.

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## MINING VOLUME MEASUREMENT SYSTEM

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION1. Field of the Invention

The present invention relates generally to length and volume measurement systems for shafts and, more specifically, to an improved method and system for measuring the length and volume of straight or curved shafts having smaller off-shooting segments from a primary segment.

2. Description of Related Art

In environments such as mine shafts, it is frequently necessary to measure the depth of the shaft to calculate the volume of the shaft. Past mechanical measurement devices for length and volume have been cumbersome. Further, such devices have been impractical if the shaft is of a significant length or is curved.

The practical limitations become particularly evident when a measuring element must be as long as the shaft itself.

Artisans have also attempted to use pulsed ultra-  
5 sonics, but an inherent drawback is that the beams cannot propagate over long distances without defraction and resulting inaccuracies from wall reflections in the measurements. Laser ranging devices have also been utilized, but those devices typically depend on reflec-  
10 tive surfaces and straight path lengths and cannot be used for a curving shaft. For open end shafts, the absence of reflective surfaces makes laser devices of limited use.

In the context of cavities that are significantly  
15 smaller than a mine shaft, artisans have also developed measurement systems that utilize principles of resonance volume. However, many have required a comparison measurement to a standard or known volume. Obviously, in the context of large mine shafts, a need for a comparison  
20 volume would render the system impractical. Even if a reference volume is not needed, volume resonance systems may not provide accurate measurements where there are off-shooting segments from the primary segment of the shaft, the latter of which is being measured. The  
25 presence of off-shooting segments tends to contribute to the overall volume that the system measures. Consequently, instead of limiting the measurement to the primary segment, the system's measurements include the off-shooting segments.

30 A need still exists in the art to provide an improved length and thus volume measurement system for large, cylindrical but irregular shaped shafts.

### SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved method and system for measuring the length and thus volume of irregular shaped shafts.

5 Another object of the present invention is to provide a method and system that measures the length and thus volume of a primary segment of an irregular shaped shaft.

10 A further object of the present invention is to provide a length and thus volume measurement system for a shaft, the system being capable of utilizing a primary segment of the shaft as a wave guide and thereby prevent off-shooting segments from affecting the accuracy of the measurements.

15 The objects of the present invention are particularly accomplished by using an effective velocity of sound in the shaft to determine shaft length. The shaft is utilized as a cylindrical wave guide and an incident wave and a reflective wave are generated in a selected  
20 portion of the shaft. At least one harmonic mode is then created with the incident wave and the reflective wave.

These and other objects of the present invention can best be seen from examination of the specification, claims, and drawings hereto.

### 25 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of the present invention utilized in the context of a mining shaft.

FIG. 2 is a partial depiction of a standing wave generated by the present invention in a mining shaft.

### 30 DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description is provided to enable any person skilled in the relevant art to make and use the

present invention and sets forth the best mode contemplated by the inventor of carrying out his invention. Various modifications, however, will remain readily apparent of those skilled in the art, since the generic principles of the present invention have been defined  
5 herein specifically to provide an improved mining volume measurement system. Furthermore, although the present invention is disclosed in the context of a mine shaft, artisans will understand that the invention can be  
10 applied in other contexts.

FIG. 1 illustrates a mine shaft 10 in which the present invention can be utilized to determine the longitudinal length and thus volume of the shaft 10. Shaft 10 is generally cylindrical in configuration and  
15 extends along a longitudinal axis A. The shaft 10 includes a primary segment 12 and a pair of off-shooting segments 14a,b. The particular number and configurations of off-shooting segments can vary according to the present invention. The primary segment 12 describes a  
20 longitudinally extending primary cavity or bore 26. The bore can meander in angle but still acts as a waveguide to the acoustic excitation described below.

As also depicted in FIG. 1, the pair of off-shooting segments 14a,b extend from the primary segment 12 and  
25 describe respective secondary bores 14a,b. The bores 14a,b remain in sound communication with the bore 26 of the primary segment 10 but are significantly smaller.

The bore 26 includes a central portion 22 and a side portion 24. The central portion 22 generally includes  
30 that cylindrical portion of the bore 26 extending along the longitudinal axis A and centrally about such axis. The side portion 24 includes that portion of the bore 26 which surrounds the central portion 22. An interior wall 20 of the primary segment 12 extends about and  
40 interfaces the bore 26.

The primary segment 12 also describes an entry or accessible end 16 at one end of the primary segment 12 for sending and receiving wave signals as described below. An end portion 18 is located at the end of the segment 12 opposite the entry 16 for acting as a boundary that produces a reflected wave described below. The present invention contemplates that, in one embodiment, the end portion 18 is closed and, in another embodiment, is open. As further described below, when the end portion 18 is closed, the primary segment 12 approximates a closed end pipe. When the end portion 18 is open, the primary segment 10 approximates an open end pipe.

A conventional acoustic generator 34, such as a shaker or speaker mounted as a piston source, is positioned adjacent the entry 16 to generate an incident signal or wave 28 into the shaft 10. Preferably, the incident signal 28 is a low frequency sound wave to propagate and be guided by the primary segment 12. As a result, the incident wave 28 does not travel into the off-shooting segments 14 or scatter off the shaft wall 20.

A power driver 40 drives the acoustic generator 34 while a frequency source 42, which is controlled by a computer controller 44, regulates the frequency and phase of the incident wave 28. A microphone 36 is located adjacent the acoustic generator 34 to receive acoustic signals from the primary segment 12.

A means (not shown) is provided whereby a computer controller 44 interrupts the frequency source 42 during the time the microphone 36 makes a measurement so as not to superimpose a shaft-reflected wave 30 (described below) with the incident wave 28 at the microphone 36.

An amplifier signal processor 38 amplifies the acoustical signals read by the microphone 36. The computer controller 44 also reads the amplified

acoustical signals from the signal processor 38. Upon reading the acoustical signals, the computer 44 can then adjust the frequency source 42 to alter the frequency of the incident wave 28.

5       As noted above, the primary segment 12 is utilized as a cylindrical wave guide. The acoustic generator generates an incident wave 28 into the primary segment 12. A reflected signal or wave 30 is generated towards the entry 16 upon the incident wave 28 impinging  
10   the boundary formed at end portion 18 of the shaft 10. This occurs whether the end portion 18 is open or closed. The computer controller 44, the frequency source 42, and the power driver 40 adjust the frequency of the incident wave 28 until a resonance mode of the  
15   fundamental frequency or a harmonic mode, which is characteristic of the primary segment 12, is read by the signal processor 38 and computer controller 44. Adjusting the frequency of the incident wave 28 and thereby the reflective wave 30 provides a standing wave 32 (FIG. 2)  
20   wherein the standing wave 32 represents either a fundamental frequency mode or harmonic mode which is characteristic of the primary segment 12.

The produced standing wave 32 can then be utilized to calculate the length of the shaft 10 according to the  
25   formula  $F = V/2L$  or  $F = V/4L$ . The first formula is utilized when the end portion 18 is open and the second formula is used when the end portion 18 is closed. In either formula,  $V$  = the effective velocity of sound in the primary segment 12,  $L$  = the length of the shaft 10,  
30   and  $F$  = the frequency at which the fundamental mode is produced. With a measured length, the volume can then be calculated.

The accuracy of the present invention is enhanced by utilizing only the primary segment 12. The existence of  
35   the off-shooting segments 14 does not add significant



inaccuracies to the measurements, as long as their size is small compared to the acoustic wavelength. Perturbations caused by interaction with the standing wave 32 and the wall 20, which would otherwise tend to cause inaccuracies, are minimized.

In an alternative embodiment of the present invention, a first standing wave 32 is produced and which is characteristic of a harmonic or resonance mode. This harmonic mode may but need not be the resonance mode of the fundamental frequency. A second standing wave 32 is then produced which is indicative of another harmonic mode, which mode is different from the former by an integral of  $\pm 1$ . The length of a closed end shaft 10, for example, can then be calculated according to the formula  $F - F_{\pm 1} = V/4L$  wherein  $F$  = the frequency of one harmonic mode and  $F_{\pm 1}$  is the frequency of another harmonic mode which is different from the former by an integral of one.  $V$  = the the velocity of sound in the primary segment 12, and  $L$  = the length of the primary shaft.

As can be appreciated, the present invention provides a method and apparatus for measuring the length of a curved or straight shaft, regardless of the existence of small off-shooting segments. The present invention provides more reliable measurements of the length of a shaft and consequently the volume of the shaft.

The specifications above describe only two preferred embodiments of the present invention, and it is contemplated that various modifications to the above can be effected but nevertheless come within the scope of the present invention as defined by the claims.

What is claimed is:

## MINING VOLUME MEASUREMENT SYSTEM

ABSTRACT OF THE DISCLOSURE

In a shaft having a curved or straight primary segment and smaller off-shooting segments, at least one standing wave is generated in the primary segment. The shaft has either an open end or a closed end and approxi-  
5 mates a cylindrical waveguide. A frequency of a standing wave that represents the fundamental mode characteristic of the primary segment can be measured. Alternatively, a frequency differential between two successive harmonic  
10 modes that are characteristic of the primary segment can be measured. In either event, the measured frequency or frequency differential is characteristic of the length and thus the volume of the shaft based on length times the bore area.

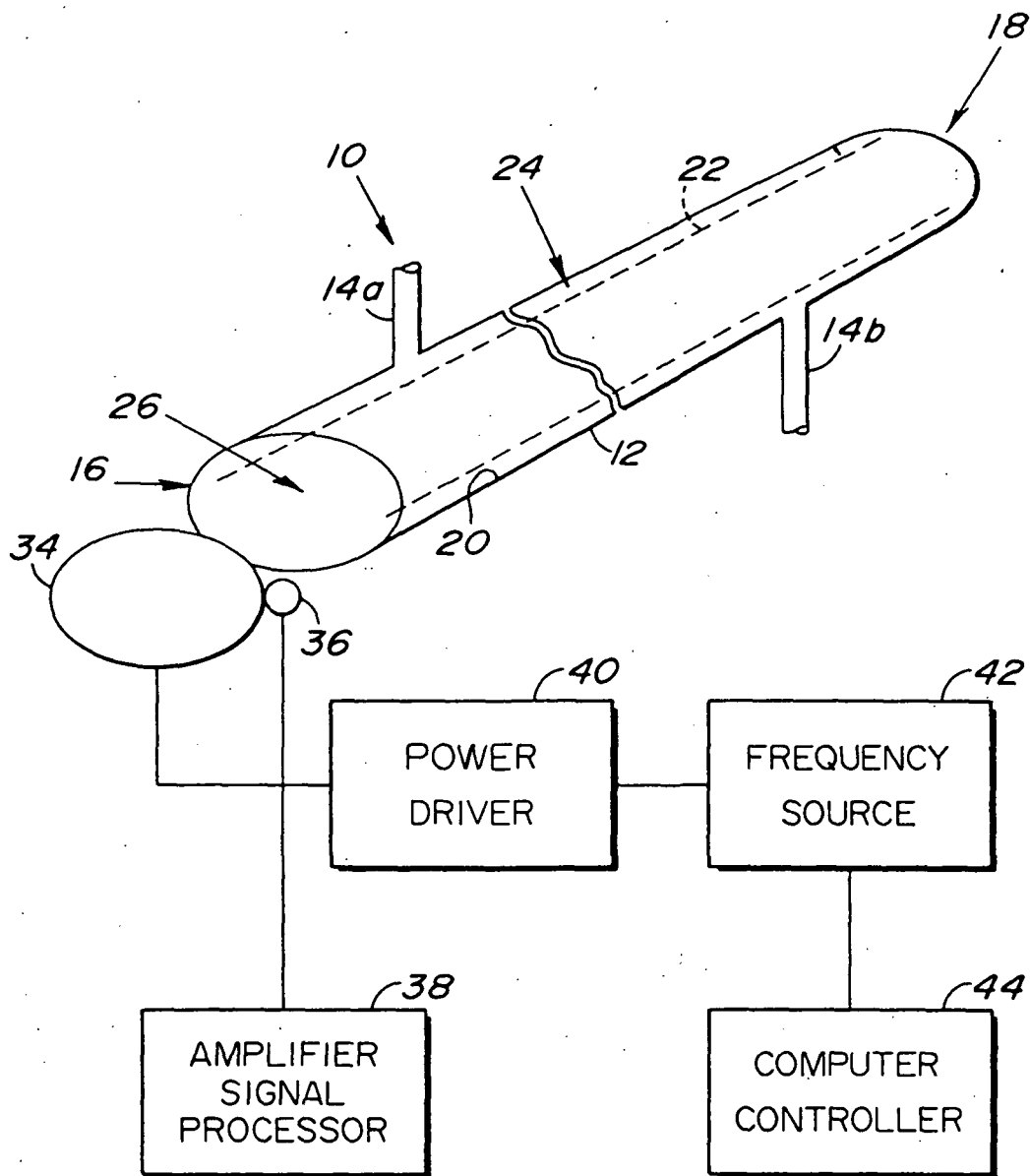


FIG. 1

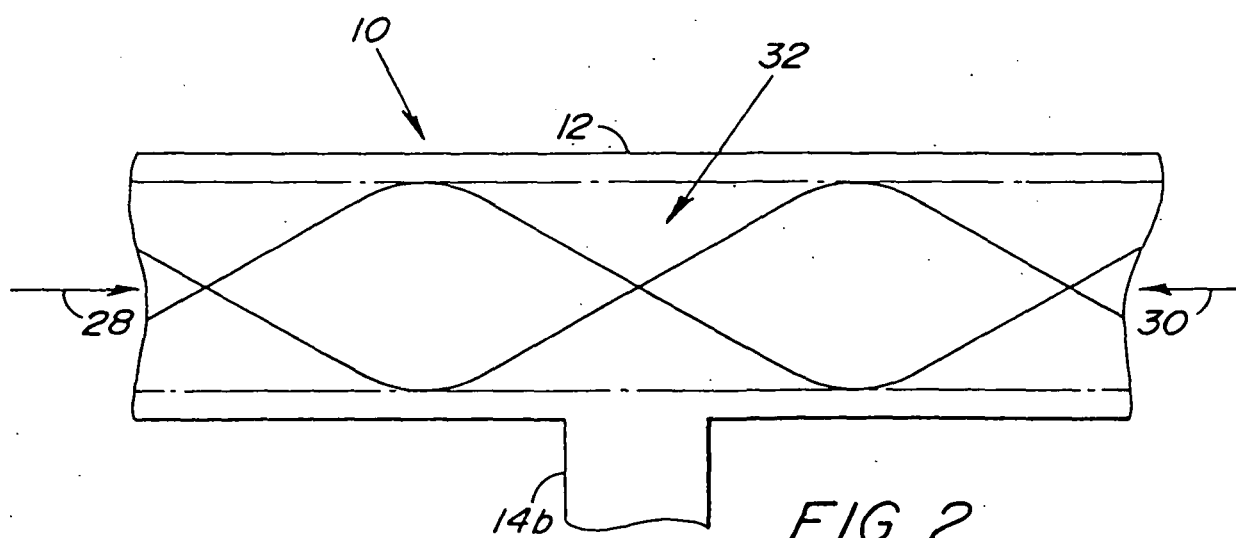


FIG. 2